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Diet Composition of Juvenile Pigfish, *Orthopristis chrysoptera* (Perciformes: Haemulidae), from the Northern Gulf of Mexico

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Diets of 954 juvenile pigfish, *Orthopristis chrysoptera,* collected from 14 1-m^3 concrete block artificial reefs approximately 20 km south of Mobile Bay, AL, were examined. A total of 137 specimens (14.4 %) contained food items and were used to perform stomach content analysis. Index of Relative Importance was used to evaluate the contribution of major foods by combining frequency of occurrence, volume, and number. Diets were dominated by shrimps and polychaetes and, to a much lesser extent, sea anemones, fishes, crustaceans, cephalopods, and gammarids. Many stomachs contained various quantities of sand, which indicated a certain amount of bottom feeding by this species. Two distinct dietary preferences based on fish size were revealed.

Of 11 species of grunts (Haemulidae) found in the Gulf of Mexico, only pigfish, *Orthopristis chrysoptera,* is common inshore. Juvenile pigfish are frequently found in shallow water and will often enter bays, estuaries, and canals (Darcy, 1983; Sutter and McIlwain, 1987). In these habitats, juveniles will readily inhabit or are found over a variety of soft substrates (mud, sand, seagrass beds), as well as rocky substrates (e.g., rock jetties). Adults, on the other hand, frequent deeper, offshore waters where they occur over sand or mud substrates; artificial habitats such as reefs, jetties, and offshore platforms (Hastings et al., 1976; Darcy, 1983; Sutter and McIlwain, 1987; Nelson and Bortone, 1996); and hard live bottom habitat (Sedberry and Van Dolah, 1984). Although pigfish are frequently taken by recreational fishers and are considered a quality food fish by some (Darcy, 1983), they have limited economic value (Joseph and Yerger, 1956). Commercially, pigfish are collected with traps, seines, trawls, and handlines where they are marketed as live bait (Sutter and McIlwain, 1987). Pigfish are also caught as bycatch by shrimp trawlers (Darcy, 1983).

On the basis of qualitative studies, pigfish are carnivorous, feeding on benthic invertebrates including polychaetes, shrimp, insect larvae, fishes, amphipods, mollusks, and crabs (Linton, 1905; Smith, 1907; Hildebrand and Schroeder, 1928). Unfortunately, these early studies did not account for ontogenetic changes in diet composition with increased fish size. Two distinct feeding phases of juvenile pigfish based on fish size were first documented by Hildebrand and Cable (1930). Juvenile pigfish (12–35 mm SL) fed primarily on copepods, whereas larger (40–100 mm SL) juveniles fed on larger crustaceans such as crabs, shrimp, and amphipods. A similar trend was later observed by Reid (1954) in a study of juvenile pigfish in Crystal River, FL. Here, a dietary shift was reported from primarily copepods consumed by fish 25–50 mm SL to a diet of amphipods and shrimp by fish 51–150 mm SL. Polychaetes were the dominant prey item of larger [151–170 mm standard length (SL)] pigfish (Reid, 1954). A dietary shift with increased fish size was also reported by Carr and Adams (1973) in pigfishes collected in Crystal River, FL. They found that juvenile pigfish 16–30 mm SL were planktivorous (consuming copepods, mysids, larval shrimp), followed by a two-phase carnivorous stage where benthic invertebrates were dominant prey items. The gradual transition from planktivore to benthivore occurred at about 26 mm SL, at which time polychaetes began to appear in the diet. The transition was completed by 41–45 mm SL. In addition, they noted that polychaetes were more important in diets of pigfish 41–55 mm SL and that specimens >55 mm SL consumed more caridean and penaeid shrimps. As adults (≥200 mm SL), pigfish are primarily benthic feeders (Darcy, 1983; Sutter and McIlwain, 1987).

Most food habit studies of pigfish have focused on juveniles ≤80 mm SL collected from inshore areas. Reid (1954) examined the stomach contents of pigfish up to 170 mm SL; however, sample size of large fish was very small (n = 10 for size class = 151–170 mm SL). Diets of pigfish (31–250 mm SL) captured with beach seine collections were examined by Vega-Cendejas et al. (1994) off the northwestern coast of the Yucatan peninsula, Mexico. Amphipods (Gammaridae) were the primary dietary component of these pigfish on the basis of percentage of weight (28.1%). Pigfish

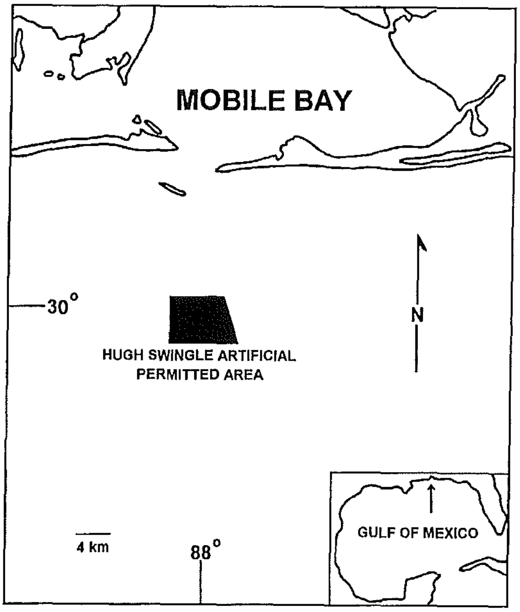

Fig. 1. Location where pigfish were collected from concrete block artificial reefs in the northern Gulf of Mexico.

also fed upon other trophic groups of lesser importance on the basis of percentage of weight such as detritus (13.2%), mollusks (10.3%), and annelids (9.3%). In a study involving pigfish associated with bridge rubble off Panama City, FL, polychaetes (24.8%) were the preferred prey (Nelson and Bortone, 1996). Unfortunately, Vega-Cendejas et al. (1994) and Nelson and Bortone (1996) did not account for ontogenetic changes in diet composition with increased fish size. The present study was designed to examine diets of juvenile pigfish ($\geq$80 mm SL), whose population was a major component of the assemblage of fishes associated with 14 offshore artificial reefs located in the northern Gulf of Mexico.

MATERIALS AND METHODS

Pigfish were collected from artificial reefs located in the Hugh Swingle artificial reef permitted area approximately 20 km south of Mobile Bay, AL (Fig. 1). In Aug. 1992 ($n = 2$) and July 1993 ($n = 12$), a total of 14 concrete block artificial reefs (1 m^3) were placed at depths of 18–23 m in the Hugh Swingle reef area. Reefs were located at a maximal distance of <1 km from each other. Reefs were not sampled for a minimum of 6 mo after deployment to allow colonization of a benthic community consisting of hydroids, barnacles, bryozoans, and algae. Sampling was conducted between 0800 and 1400 hr CDT. All pigfish were collected by SCUBA divers with a drop net (3.0 m radius, 1.3-cm^2 mesh). Divers positioned themselves approximately 5 m (less if visibility was poor) away from the reef and waited for the fishes to resume "normal" behavior. Once fishes were acclimated to the presence of the divers, the divers swam up and over the reef positioning the drop net directly over the reef (Fig. 2). Once the lead line of the net was positioned around the reef, edges of the net were brought in toward the perimeter of the reef. In order to calm the fishes and to flush some specimens out of the reef's infrastructure, rotenone was occasionally squirted into the reef. No fishes were observed regurgitating stomach contents when rotenone was used. Afterward, the net was carefully lifted over one side of the reef, and the entire drop net and fishes were placed in a mesh game bag. On the boat, all fishes were removed from the game bag, placed in ice, and transported back to the laboratory.

Approximately 18–24 hr after collection, the pigfish were thawed, and total length (TL), fork length (FL), and SL were measured to the nearest 1.0 mm and whole body weight determined to the nearest 0.1 g. Body length measurements conformed to definitions in Hubbs

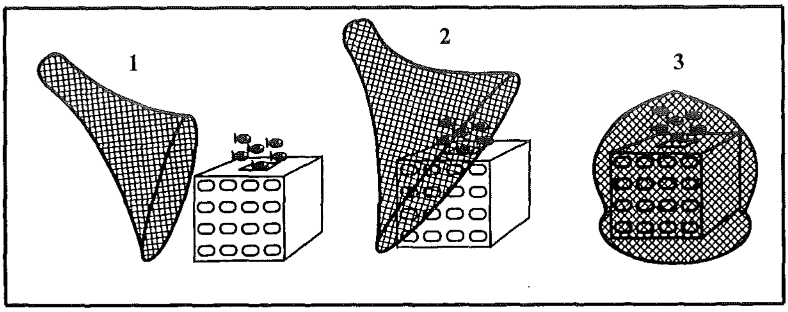

Fig. 2. How the drop net was used to collect fishes associated with the concrete block artificial reefs.

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and Lagler (1964). Stomachs were removed and stored in 10% buffered formalin for a minimum of 96 hr, after which time they were rinsed and stored in 50% isopropyl alcohol until identification and analysis could be completed. Empty stomachs were noted and discarded. Stomach contents were sorted, counted, and identified to the lowest practical taxon. Bowen (1983) stated that in most predator–prey interaction studies, order or family is a low enough taxon for prey identification and little additional information is gained by identifying prey items to the species level. If a food item was fragmented, indicator parts were counted to estimate the number of organisms.

Dietary coefficients described by Hyslop (1980) were used, and empty stomachs were excluded from computations. The frequency of occurrence (F) of prey items was determined by counting the number of stomachs that contained at least one specimen or part of a specific taxon (e.g., head, carapace, cheliped) and expressed as a percentage of all stomachs containing food ($n = 137$). Number of individuals (N) in each food category was recorded for all stomachs and expressed as a proportion. For example, if three separate items were identified from a single stomach that could have come from a single specimen, the items were counted as one rather than three. Volume (V) was calculated with a graduated cylinder or syringe to the nearest 0.1 ml or 0.01 ml, respectively, and expressed as a percentage of the total volume of all stomach contents. All data were analyzed as percentage frequency of occurrence (%F), percentage of total number (%N), and percentage of food volume (%V). These dietary coefficients were used to calculate an Index of Relative Importance (IRI) in order to estimate the contribution of major food groups to the diet (Pinkas et al., 1971). The Index of Relative Importance was calculated as:

$$\mathrm{IRI} = (V + N)F,$$

where N = numerical percentage of a food, V = volumetric percentage, and F = percentage frequency of occurrence. IRI was converted to % IRI as follows:

$$\%\mathrm{IRI} = (\text{prey item IRI}/\text{total IRI}) \times 100,$$

for more meaningful comparisons. The IRI was used because each of the three calculated variables (F, N, V) has certain biases that can be reduced by using this index (Hyslop, 1980).

RESULTS

A total of 954 pigfish, 80–208 mm SL, were collected in 1993 (June, Oct.), 1994 (May, June, Aug.–Dec.), and 1997 (Sep.) in the northern Gulf of Mexico (Fig. 1). Because of the small number of specimens collected in 1993 ($n = 53$) and in 1997 ($n = 44$), the data were pooled from all 3 yr for data analysis. Of these, stomachs of 137 (14.4 %) pigfish, 108–198 mm SL, contained prey items whereas the other 817 (85.6 %) stomachs were empty. Stomach content analysis revealed that pigfish have a varied diet (Table 1). On the basis of frequency percentage, volume percentage, and IRI, the dominant prey items were shrimps, polychaetes, sea anemones, fishes, and other crustaceans. The 137 pigfish were separated into two different size classes to investigate distinct feeding phases on the basis of fish body length. Although the data were analyzed with a series of different size classes, the shift in dietary importance was most evident when separated at a 150 mm SL that also coincided with Reid's (1954) study. Prey items of smaller (108–150 mm SL) pigfish were dominated by polychaetes, followed by shrimp, sea anemones, crustaceans, and gammarids (Table 1). In larger (151–198 mm SL) pigfish, a shift in dietary importance from polychaetes to shrimp was observed (Table 1). Shrimp was by far the dominant prey item and, to a lesser extent, polychaetes, fishes, sea anemones, and cephalopods.

DISCUSSION

Diets of pigfish examined in the present study corresponded well with previously published accounts (Linton, 1905; Smith, 1907; Hildebrand and Schroeder, 1928; Hildebrand and Cable, 1930; Reid, 1954; Carr and Adams, 1973; Darcy, 1983; Sutter and McIlwain, 1987). Pigfish are carnivorous, with benthic invertebrates the most important food items. This finding is further supported by the fact that many stomachs contained various amounts of sand, which could indicate bottom feeding by this species. Although species composition of prey is most likely different between offshore and inshore areas, the diet of pigfish collected offshore in the present study was typical of fish collected from inshore areas (Reid, 1954; Carr and Adams, 1973; Vega-Cendejas et al., 1994) with respect to general trophic classes. This diet would indicate that pigfish are general omnivores and are not involved in species-specific predation.

TABLE 1. Frequency of occurrence (%F), percentage of number (%N), percentage of volume (%V), and percentage of Index of Relative Importance (%IRI) regarding stomach contents of pigfish collected approximately 20 km south of Mobile Bay, AL. The stomachs (N = 137) examined were separated into two size classes (108–150 mm SL and 151–198 mm SL) to examine distinct feeding phases on the basis of body size.

	Size class											
	108–150 mm SL (n = 83)				151–198 mm SL (n = 54)				108–198 mm SL (n = 137)			
Prey item	%F	%N	%V	%IRI	%F	%N	%V	%IRI	%F	%N	%V	%IRI
Annelida												
Hirudinea	2.41	0.84	0.01	0.04	1.85	0.27	0.01	0.01	2.19	0.55	0.01	0.02
Polychaeta	37.35	42.13	12.94	41.01	35.19	18.68	13.81	17.74	36.50	30.28	13.44	30.34
Anthozoa												
Sea anemones	12.05	3.09	12.13	3.66	7.41	1.09	5.98	0.81	10.22	2.08	8.63	2.08
Chaetognatha	1.20	0.28	0.01	0.01					0.73	0.14	0.01	0.01
Crustacea (unidentified)	8.43	1.97	7.03	1.51	5.55	0.82	1.39	0.19	7.30	1.39	3.81	0.72
Copepoda	1.20	1.69	0.01	0.04	3.70	0.82	0.01	0.05	2.19	1.25	0.01	0.05
Gammaridae	3.61	13.76	0.04	0.99					2.19	6.81	0.02	0.28
Other Amphipoda	1.20	0.28	0.01	0.01					0.73	0.14	0.01	0.01
Hyperiidae	2.41	0.56	0.01	0.03					1.46	0.28	0.01	0.01
Isopoda	1.20	0.28	0.01	0.01					0.73	0.14	0.01	0.01
Mysidacea	1.20	0.28	0.01	0.01					0.73	0.14	0.01	0.01
Decapoda (unidentified)	4.82	1.40	0.29	0.16	3.70	0.55	0.37	0.05	4.38	0.97	0.34	0.11
Portunidae					1.85	0.55	0.03	0.02	0.73	0.28	0.02	0.01
Penaeidae	42.17	15.17	14.46	24.91	72.22	23.35	40.83	71.93	54.02	19.31	29.49	50.12
Xanthidae	2.41	1.12	0.04	0.05					1.46	0.55	0.02	0.02
Echinodermata												
Asteroidea	4.82	1.69	0.08	0.17	1.85	0.27	0.02	0.01	3.65	0.97	0.04	0.07
Hydrozoa	4.82	1.12	1.01	0.20					2.92	0.55	0.43	0.05
Mollusca (unidentified)	1.20	0.28	0.01	0.01	1.85	0.27	0.03	0.01	1.46	0.28	0.01	0.01
Cephalopoda	2.41	0.56	7.87	0.41	3.70	0.82	5.73	0.37	2.92	0.69	6.65	0.41
Gastropoda	2.41	1.12	0.88	0.10					1.46	0.55	0.38	0.03
Bivalvia	1.20	0.56	0.01	0.01	1.85	0.27	0.01	0.01	1.46	0.42	0.01	0.01
Osteichthyes	2.41	0.84	1.09	0.09	11.11	2.75	19.44	3.83	5.84	1.81	11.54	1.48
Scales	6.02	3.09	0.02	0.37	1.85	3.30	0.01	0.09	4.38	3.19	0.01	0.27
Porifera (spicules)					1.85	1.65	0.01	0.05	0.73	0.83	0.01	0.01
Sand	1.20	0.28	0.08	0.01	1.85	0.27	0.05	0.01	1.46	0.28	0.06	0.01
Unidentified matter	26.51	7.58	41.97	26.19	20.37	3.02	12.25	4.83	24.09	5.28	25.03	13.88

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Previous studies (Hildebrand and Cable, 1930; Reid, 1954; Carr and Adams, 1973) established distinct feeding phases in juvenile pigfish collected inshore according to growth stage. Although Vega-Cendejas et al. (1994) examined both juvenile and adult pigfish, they did not investigate dietary preferences on the basis of body size. In the present study, a shift in dietary preference of large juvenile pigfish based on body size was documented. The dominant prey item of smaller (108–150 mm SL) juveniles was polychates, whereas larger (151–198 mm SL) specimens preferred shrimp. The difference in sampling location, the small number of stomachs (especially in the 151–170 mm range) examined by Reid (1954), and the potential impact of the artificial reefs on prey diversity and abundance could impart explain why the results of our study were opposite of Reid's (1954). In contrast, Nelson and Bortone (1996) placed pigfish in feeding guild E (upper structure predators), which was composed of fishes with unclear feeding preferences.

The fact that pigfish in the present study were collected during 0800–1400 hr, the high percentages of frequency and volume, and the high IRI value for unidentified, partially digested matter would suggest that pigfish forage late in the day or evening hours. Evidence suggesting that pigfish may feed at night was the high percentage (85.6%) of empty stomachs reported in the present study. This finding corresponds with observations (Hastings et al., 1976; Darcy, 1983) that pigfish are probably nocturnal feeders, leaving shelter at dusk to forage and returning to shelter before dawn. However, the percentage of empty stomachs could also be related to the nocturnal foraging migrations of pigfish away from the reefs. Pigfish density and the distance they travel away from the reefs could directly impact the density of available prey. Telemetry studies would be necessary to gain more insight into these nocturnal migrations. Furthermore, the smaller size class (108–150 mm SL) of pigfish revealed a greater percentage of volume and IRI for unidentified and partially digested matter. This suggests that 1) smaller individuals may forage during the late day and early evening hours and seek shelter during the late evening and early morning hours when larger individuals may be foraging, or 2) these smaller pigfish may consume smaller prey that could be digested faster. Additional support suggesting that smaller juvenile pigfish feed during the day was documented by Adams (1976). To complicate matters, the high values of unidentifiable matter may represent soft-bodied prey, which would be digested more rapidly and earlier than hard-bodied prey. Consequently, future diet-related studies involving pigfish should involve both day and night sampling. In addition, ontogenetic shifts in diet have often been linked to morphological variation in feeding apparatus. Therefore, potential differences in feeding apparatus of pigfish need to be examined.

This is the first study to document ontogenetic changes in diet composition of juvenile pigfish associated with artificial reefs off the coast of Alabama. It is evident that pigfish are commonly attracted to demersal artificial structures where these reefs appear to be important as a form of shelter; however, it would appear that they regularly migrate away from these reefs during the night. The extent of feeding on prey directly associated with the reef is uncertain, but feeding away from the reef appears to be important. Unfortunately, the trophic habits, foraging migrations, and competitive interactions of fishes associated with artificial reefs have not been studied extensively. These items will need to be addressed in order to gain a better understanding of the trophic dynamics of artificial reef fish assemblages and how this affects community structure.

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